

Inventory Investment and Economic Instability

INVENTORY investment—the difference between production and final sales—can be either a stabilizing or a destabilizing factor in economic fluctuations. For example, if a drop in final sales leads to an involuntary accumulation of inventories of finished goods, then inventory investment is playing a stabilizing role, because production has fallen less than sales have fallen. But if the lower level of final sales persists and the swollen level of inventories is deliberately reduced by driving production below sales, then inventory investment is playing a destabilizing role.

As has often been documented, inventory investment has usually been destabilizing. This article measures the extent to which various categories of inventories have been destabilizing and, for manufacturers' inventories, explains the destabilizing behavior in terms of the contributions of factors that influence inventory investment.

The article makes intensive use of the estimates of constant-dollar manufacturers' inventories by stage of fabrication introduced by BEA as part of the 1980 comprehensive revisions of the national income and product accounts.¹ The new estimates are built up from separate estimates of inventories of materials, goods in process, and finished goods in each of 20 manufacturing industries. This article explores some aspects of what the new estimates tell about the behavior of inventories.

The first section of the article develops a statistical measure of the extent to which inventory investment contributes to economic instability.

The measure is presented for total inventory investment, and for inventory investment at different stages of the production process and at different cyclical stages. The second section presents demand equations for manufacturers' inventory holdings by stage of fabrication; these equations permit further analysis of the destabilizing behavior by measuring separately the contribution of various influences—sales, new orders, and the financial cost of holding inventories—on inventory investment. The final section presents simulations of manufacturers' inventory behavior under different demand and cost conditions.

The analysis indicates that manufacturing inventory investment in total is destabilizing. However, the extent to which it is destabilizing differs substantially by stage of fabrication. For finished goods inventory investment, neither stabilizing nor destabilizing behavior dominates; in the early stages of cyclical fluctuations, inventory behavior tends to be stabilizing, but in later stages, it is mixed. Investment in both work-in-process inventories and materials inventories is destabilizing, and this behavior is apparent at all stages of cyclical fluctuation.

Inventories in all three stages of fabrication respond positively to levels of demand, as measured by sales and new orders, and negatively to the financial cost of holding inventories. The finding of a response to the latter, as measured by a real rate of interest, contrasts with the findings of much previous analysis. The contrast in findings, at least in part, is due to the inclusion in the sample period used for this article of the wide swings in real interest rates of the 1970's. The response to demand is stronger for work-in-process and ma-

terials inventories than for finished goods inventories, and this difference accounts, at least in part, for the difference in stabilizing/destabilizing behavior.

The Contribution of Inventory Investment to Instability

The measure proposed in this article is an answer to the question: How much more instability is there in production than in final sales? The measure can be calculated for total inventory investment, for inventory investment by stage of fabrication and by industry, for expansions and contractions, and for many other groupings of inventory estimates.

The measure is the percent difference between two measures of dispersion. One of the two is the root-mean-square (i.e., the square root of the mean squared value) of the percentage deviation of final sales of goods and structures (in 1972 dollars) from its trend. The other is the root-mean-square of the percentage deviation of final sales plus inventory change—i.e., production—from its trend. If sales relative to its trend has a root-mean-square deviation of 2.4 percent and sales plus inventory change relative to its trend has root-mean-square deviation of 3.0 percent, then the measure equals 25, the 25 percent excess of 3.0 over 2.4. (As will be seen, these are the actual figures in the calculation for total inventory change in 1959-81.) The measure is always positive if inventory change is destabilizing. If some category of inventory change has a stabilizing influence, so that the deviation from trend of sales plus that category of inventory

1. The new estimates are described in John C. Hinrichs and Anthony D. Eckman, "Constant-Dollar Manufacturers' Inventories," *SURVEY OF CURRENT BUSINESS* 61 (November 1981): 16-23.

change is smaller than the deviation of sales alone, then the measure will be negative.²

In mathematical terms, the measure (M) is:

$$M = 100 \left(\frac{S_t - S_s}{S_s} \right)$$

where S_t is the square root of the mean square percent deviation from trend of constant-dollar final sales of goods and structures plus inventory change, and S_s is the square root of the mean square percent deviation from trend of final sales of goods and structures. The sales trend is a centered 21-quarter moving average of actual sales.³ The trend of inventory

change is equal to the sales trend times the ratio of mean 1959-81 inventory change to mean 1959-81 sales, and the trend of sales plus inventory change is equal to the sum of the sales trend and the inventory change trend. Sales, and thus S_s , is identical in calculation of the measures for total inventories and for inventory categories. In contrast, actual and mean inventory change, and thus the trend of inventory change and S_t , is specific to the inventory total or categories.⁴

The measure is a descriptive one, influenced by all of the forces that affect inventories and final sales. It does not separate, for example, "involuntary" from "voluntary" inventory investment, or "passive" from "active" inventory behavior. However,

4. It would be possible to construct an alternative measure in which sales as well as inventory change differed by category. If S_s is the root-mean-square percent deviation from trend of some alternative sales series, then the relation between M' , the measure of instability employing the alternative sales series, and M , the measure of instability used in this article, is given by:

$$\frac{M' + 100}{M + 100} = \frac{S_s}{S'_s}$$

The alternative measure is less useful than the one in this article for decomposing an aggregate measure into the contribution of different inventory categories; but it might be more useful for an analysis of inventory investment in a specific industry.

the measure should be useful to forecasters in judging whether a set of sales and inventory investment projections conforms to, or departs from, the usual historical relation of inventory investment to sales. The measure should also be useful to builders of models of the economy in judging whether shocks imposed on their models produce sales and inventory investment outcomes that are realistic.

Results

For major inventory categories.—Table 1 presents the measure for major categories of inventories for 1959-81 and two subperiods. For the entire period, production was 25 percent more unstable than final sales. The root-mean-square deviation from trend was 3.01 percent for production and 2.42 percent for sales. Chart 7 shows the two time series underlying this measure: the percentage deviation of final sales relative to its trend and the percentage deviation of production, or sales plus inventory change, relative to its trend.

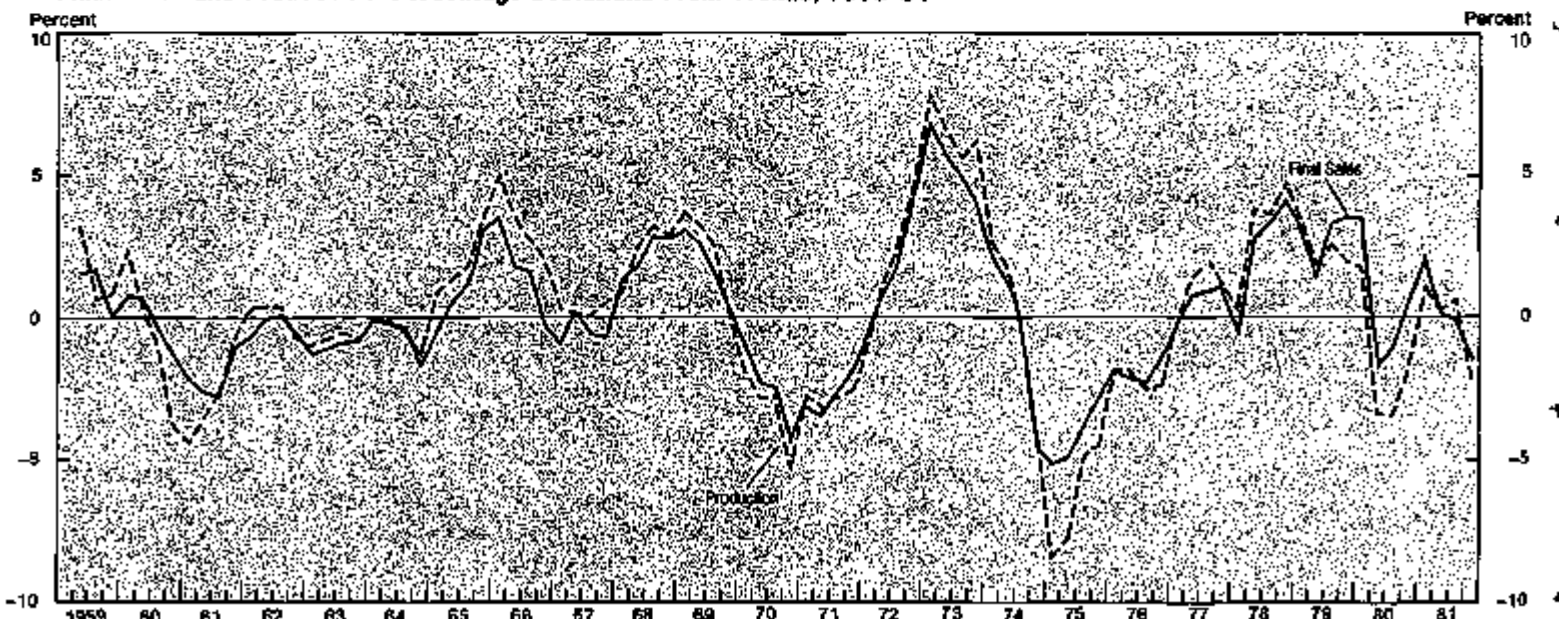
For the period as a whole, farm inventories contributed little to the overall destabilizing effect, and within the nonfarm group, manufacturing contributed most. Within manufactur-

2. The possibility of negative values points to the difference between the measure of instability used in this article and a measure based on an analysis of the variance of output by component, often used by others (see, for example, Alan Blinder, "Retail Inventory Behavior and Business Fluctuations," *Brookings Papers on Economic Activity*, No. 2 (1981) pp. 445-9). In an analysis of variance, inventory investment will make a positive contribution to total variance irrespective of whether it is stabilizing or destabilizing; only the covariance terms can discriminate between the two situations. The measure used here depends on both the variance of inventory investment and the covariance of inventory investment and sales.

3. The trend was extended to the end of 1981 by using an autoregressive equation to project changes in sales and then using projected sales to calculate the moving average. The autoregressive equation was $\Delta LS_t = 0.0049 + 0.2429 \Delta LS_{t-1}$, where ΔLS is the change from the preceding quarter in the logarithm of sales.

CHART 7

Final Sales and Production: Percentage Deviations From Trends, 1959-81



Note.—Final sales refers to final sales of goods and structures, in 1972 dollars. Production refers to final sales of goods and structures plus inventory change, in 1972 dollars. Percentage deviations are from trends based on 21 quarter moving averages.

Table 1.—A Measure of the Contribution of Inventory Investment to Instability, 1959-81 and Subperiods

(Percent)			
Inventory category	1959-70 1961:4	1970-81 1970:2	1970-81 1981:4
Total	25	38	32
Farm	1	-1	2
Nonfarm	24	39	30
Manufacturing	18	19	12
Finished goods	-1	3	-2
Work in process	5	6	7
Materials	6	5	6
Wholesale trade	2	3	2
Retail trade	5	11	4
Other	1	0	2
Root-mean-square percent deviation of sales from trend (S ₁)	2.42	1.80	3.01
Root-mean-square percent deviation of production from trend (S ₂)	3.01	2.15	3.66

Note.—The measure presented is equal to 100 ($S_1 - S_2$)/ S_1 , where S_1 is the root-mean-square deviation of final sales of goods and structures plus inventory change from its trend and S_2 is the root-mean-square percent deviation of final sales of goods and structures from its trend. Sales and inventory change are measured in constant dollars. See text for further description, and see footnote 5 for discussion of additivity of the measure.

ing, inventory investment in finished goods was slightly stabilizing. Investment in work in process and in materials were destabilizing.⁵ That they were destabilizing does not necessarily mean that inventory levels moved differently from final sales or from production; even if the level of inventories at some stage were perfectly proportional to production, inventory investment—the change in the level—could easily be destabilizing.

Inventory investment was more destabilizing in 1959-70 than in 1970-81. Both sales and production fluctuated less in 1959-70 than in 1970-81; but the percentage difference between the two was larger in the first subperiod. Manufacturing inventory investment was the most destabilizing nonfarm component in both subperiods. Within manufacturing, inventories of finished goods were destabilizing

during the first subperiod but stabilizing in the second; the other stages were destabilizing in both subperiods. Retail inventory investment was also destabilizing, but more so in the first subperiod than the second.

These results are moderately sensitive to the choice of a trend line for final sales. For a 17-quarter average (instead of a 21-quarter average), results are much the same. For a 5-quarter average, results are still similar for the entire 1959-81 period but are different for subperiods.

By cyclical stage.—The measure can be disaggregated by cyclical stage. For runs of deviations—positive or negative—of final sales from trend, the quarters are grouped into an early stage (first three quarters of a deviation), a middle stage (fourth through sixth quarters), and a late stage (seventh quarter and later), and the measure calculated for the observations of these stages. The resulting measures can be used to investigate whether inventory investment is more destabilizing in the early, middle, or late stages.

Table 2.—A Measure of the Contribution of Inventory Investment to Instability, by Stage of Deviations of Final Sales From Trend, 1959-81

(Percent)			
Inventory category	Stage		
	Early (first three quarters; 31 observations)	Middle (4th through 6th quarters; 35 observations)	Late (7th and later quarters; 35 observations)
Total	39	34	19
Farm	1	0	4
Nonfarm	38	34	6
Manufacturing	11	15	11
Finished goods	-5	1	-1
Work in process	10	8	5
Materials	4	7	6
Wholesale trade	2	3	0
Retail trade	16	3	-4
Other	6	1	-2
Root-mean-square percent deviation of sales from trend (S ₁)	2.06	3.30	1.90
Root-mean-square percent deviation of production from trend (S ₂)	2.06	4.09	2.03

Note.—For description of the measure, see text and note to table 1.

For runs of deviations—positive or negative—of final sales from trend, the quarters are grouped into early, middle, and late stages, and the measure calculated for the observations in these stages. A one-quarter interruption (e.g., one negative deviation surrounded by positive deviations) is not defined as ending a run.

Table 2 shows large differences in the measure of instability disaggregated in this way. For total inventory investment the measure of instability is 39 in the early stage of a deviation from trend, but only 24 in the middle stage and still smaller in the late stage. The same pattern holds true for the retail component, which has a destabilizing measure of 16 for the early stage but only 5 for the middle stage, and -4 in the late stage. In contrast, the manufacturing component destabilizes by about the same amount in each stage. Finished manufacturing inventories are stabilizing in the early stages; i.e., they tend to be reduced early in an expansion or increased early in a cyclical contraction. In later stages, however, finished goods inventories have very little impact. Inventories of work in process are destabilizing at all stages but more strongly in the early stage. Materials inventories are moderately destabilizing at all stages.

Inventory Demand Equations by Stage of Fabrication

To analyze the manufacturing results more thoroughly, it is helpful to estimate demand equations relating manufacturers' inventory holdings to measures of demand and cost. With these equations it is possible to explain, at least in part, the destabilizing or stabilizing behavior of manufacturers' inventory investment in terms of the contributions of current and lagged demand and cost variables.

Theories of inventory behavior suggest that inventory holdings ought to depend on the level of demand and on the cost of holding inventories.⁶ The response to a change in demand—usually measured by sales or new orders—depends on whether the change is accompanied by a parallel change in the number of establish-

6. See for example, Kenneth J. Arrow, Samuel Karlin, and Herbert Scarf, *Studies in the Mathematical Theory of Inventory and Production* (Stanford: University Press, 1958); Michael Lovell, "Manufacturers' Inventories, Sales Expectations, and the Acceleration Principle," *Econometrica* 29 (July 1961): 293-314; Charles C. Holt, Franco Modigliani, John Muth, and Herbert Simon, *Planning Production, Inventories and Work Force* (Englewood Cliffs, NJ: Prentice Hall, 1960); and Blinder, "Retail Inventory Behavior," pp. 443-520.

ments doing business, or whether it represents a change in the amount of activity within the typical establishment. In the former case, almost any theory would imply an elasticity with respect to sales or orders close to 1.0—that is, a proportional response of inventories to a change in sales or orders, at least after a suitable time-lag. In the latter case, however, some theories imply that within an establishment economies of scale permit a less-than-proportional response of inventories to sales. One strand of the operations research literature emphasizes a “square-root rule” in which the elasticity of inventories with respect to sales or orders is 0.5. Thus, elasticities of inventory holdings with respect to sales or orders in the range of 0.5 to 1.0 appear theoretically plausible.

Most empirical studies of inventory holdings have found that there are sizable lags in the adjustment of inventories to a change in sales or orders. Theories often allow for a short period in which inventories, especially inventories of finished goods, move in the opposite direction to changes in demand, due to the buffer-stock role of inventories. But apart from this initial “involuntary” response, there is little explanation in the theoretical literature for the widespread empirical conclusion that inventories may take as long as a year or two to adjust to a change in the level of sales or new orders.⁷

Although in theory, the cost of holding inventories is an important influence on demand, empirical work has usually been unsuccessful in uncovering a cost influence.⁸ Most of this work has emphasized a single element of cost, the interest rate on borrowed funds. There are, in fact, many other cost elements to be taken into account—the cost of physical storage, deterioration and obsolescence, insurance, taxes, and—most importantly in

recent years—expected changes in prices during the inventory holding period. A sufficiently high rate of increase in price can make the carrying costs of inventories negative rather than positive. The composite cost variable in this article, a real interest rate adjusted for the tax treatment of inventories, is a more comprehensive measure than the usual one. Even this measure, however, omits such cost elements as storage, insurance, and deterioration.

Problems of measurement are unusually severe for inventories and for real interest rates. For inventories, the problems are least serious for annual estimates, more serious for quarterly estimates, and most serious of all for monthly estimates, especially for seasonally adjusted, constant-dollar estimates. Seasonal adjustment is one example of an imperfect procedure that has far more impact on quarterly and monthly estimates than on annual estimates, but it is by no means the only one. Information on the extent of the use of the various business inventory accounting methods is essential for the construction of the estimates. Such information, as a rule, is available only on an annual basis, and is interpolated smoothly for the construction of quarterly and monthly estimates. Choosing the appropriate lags in the wholesale prices used in construction of the estimates is a more serious problem monthly and quarterly than annually. Inventory book values, the starting point for the estimates, are available for a much larger and better constructed sample on an annual basis than they are on a quarterly and monthly basis.⁹

Major problems in measuring real interest rates include the estimation of percent changes in sales prices by industry and determination of appropriate marginal tax rates as influenced not only by statutory rates, but also by the use of different inventory accounting systems.¹⁰ The real inter-

est rate measures in this article are more carefully constructed than is typical of other inventory studies. Nevertheless, these measures are undoubtedly based on much more accurate information annually than over any shorter span.

The demand equations

Separate demand equations are estimated for six categories of manufacturers' inventories, two equations each for materials, goods in process, and finished goods. One equation of each pair covers industries for which sales is the demand variable (roughly, nondurable goods manufacturing industries) and the other, industries for which new orders is the demand variable (roughly, durable goods manufacturing industries).¹¹ The dependent variables in the six equations are the logarithms of end-of-year inventory holdings in constant dollars.

For the sales industries, the independent variables are the logarithm of sales in constant dollars and a real interest rate. For the new orders industries, the variables are the logarithm of new orders in constant dollars and a real interest rate. New orders are converted from current to constant dollars by dividing by sales deflators. In most industries, new orders in quarter t are deflated by the sales deflator in quarter $t+1$ to allow for the fact that price quotations generally refer to goods sold currently, and hence ordered sometime previously.

The real interest rate variable is constructed separately for each two-digit manufacturing industry and then aggregated to the level of all sales industries and all new orders industries. The basic formula for the real interest rate is:

$$R - \left(\frac{1-ft}{1-t} \right) \dot{P}$$

where R is a short-term interest rate (specifically, the Federal Reserve series for bank rates on short-term business loans), \dot{P} is the most recent

7. In some empirical work, this lag is referred to as a slow speed of adjustment; in other work, as a slowly changing inventory “target.” The problem of finding a theoretical explanation is much the same in either case. For discussion of the problem, see Blinder, “Retail Inventory Behavior,” and Martin Feldstein and Allan Auerbach, “Inventory Behavior in Durable Goods Manufacturing: the Target-Adjustment Model,” *Brookings Papers on Economic Activity*, No. 2 (1976) pp. 351-96.

8. P. Owen Irvine, Jr., “Retail Inventory Investment and the Cost of Capital,” *American Economic Review* 71 (September 1981): pp. 533-46, is a conspicuous recent exception.

9. For a review of data problems, see Murray F. Foss, Gary Fromm, and Irving Rottenberg, *Measurement of Business Inventories* (U.S. Department of Commerce, Bureau of the Census, Economic Research Report 3 (Washington, D.C.: U.S. GPO, 1980)).

10. In particular, LIFO accounting affects taxes because increases in the value of inventories during the period in which they are held are not subject to tax for firms using this accounting system. For a description of the influence of LIFO accounting on inventory estimates, see Hinrichs, “Inventories.”

11. Note that the sales series used in this section of the article is manufacturers' shipments, including intermediate as well as final products. It is not the final sales series used in the first part of the article. The exceptions to the durable-nondurable split are lumber and furniture, which are durable goods industries but for which no new orders data are published separately. They are classified as sales industries for the purpose of this article.

annual rate of price increase for the sales of an industry, f is the proportion of each industry using non-LIFO accounting systems, and t is the statutory corporate tax rate.¹² Estimates of f are based on Census Bureau annual surveys starting with 1974 and BEA surveys before 1974. They are smoothed before being used to calculate real interest rates.

Both the demand variables and the real interest rate are split into two components, drawing on past studies about how sales expectations are formed and about how interest rate and price expectations are formed. For the demand variables—sales and new orders—the split is between last year's level and the change from last year to the current year.¹³ For the real interest rate, the split is between an "expected" component and an "unexpected" component, with the "expected" component calculated from lagged actual values and its own lagged values.¹⁴ Because each variable is split into two components, the logarithm of inventory holdings is related to four variables; the logarithm of lagged sales or new orders, the change in the logarithm of sales or new orders, the expected real interest rate, and the unexpected real interest rate.

Regression results

The inventory demand equations presented in this article are estimated using annual data as well as quarterly data. Comparisons of the two sets of results will reveal important differences—differences that could well be due to measurement errors in the quarterly data.

Annual results.—The results of the estimation are shown in table 3. Of

Table 3.—Demand Equations for Inventories: Annual Regression Results

	Sales industries			Orders industries		
	Finished goods inventories	Goods in process inventories	Materials inventories	Finished goods inventories	Goods in process inventories	Materials inventories
Constant	-2.18 (-8.5)	-5.60 (-16.0)	-2.44 (-8.2)	0.60 (2.8)	-1.89 (-2.8)	-2.99 (-7.3)
Logarithm of sales or new orders lagged one year	.81 (8.4)	1.19 (21.5)	.84 (18.0)	.37 (3.1)	.86 (7.1)	1.00 (15.2)
Change, logarithm of sales or new orders	.68 (2.9)	.81 (5.1)	.69 (4.2)	.0 (.0)	.27 (2.4)	.36 (8.1)
Expected real interest rate ¹	-.88 (-1.0)	-.63 (-1.1)	-1.59 (-3.7)	-1.87 (-1.9)	-2.33 (-2.2)	-3.09 (-4.2)
Unexpected real interest rate ¹	.49 (.4)	.12 (.1)	-.16 (-1.2)	.39 (1.3)	.35 (1.1)	.09 (.3)
R^2	.98	.99	.99	.97	.98	.98
Autocorrelation coefficient	.87	.86	.82	.88	.85	.81
D-W	1.7	1.7	1.7	1.4	1.5	1.7

NOTE.—The dependent variables are logarithms of the levels of inventory stocks at the end of each year. Numbers in parentheses are t -ratios.

1. The real interest rate is expressed in decimal form; e.g., 4 percent is 0.04. Separation into expected and unexpected components is based on the formula $XE_t = a + b(X_{t-1} + XE_{t-1})$ where XE_t is the expected rate in year t and X_{t-1} and XE_{t-1} are the actual and expected rates in year $t-1$. The unexpected rate is the actual rate minus the expected rate. See text for further explanation.

the six sales or new orders coefficients, one is below (but not significantly below) 0.5, four lie between 0.5 and 1.0, and one is above 1.0. These coefficients, which represent long-run elasticities—i.e., percent responses of inventories to a 1-percent increase in sales or new orders—generally accord with theoretical expectations.

Five of the six coefficients for the change in sales or new orders are positive and smaller than coefficients for lagged levels; the sixth coefficient is zero. This result implies that inventories respond positively both to this year's sales or new orders and last year's sales or new order.¹⁵ The result confirms past findings of a significant lag in inventories behind sales or new orders, although it does not provide any insight into why sizable lags should exist. Coefficients of change in demand are smaller for the finished goods stage of each group than for the other stages. Had these coefficients been negative, they would have been consistent with a temporary "involuntary" response of finished goods inventories to current sales or new orders before the long-run positive response dominates. In these annual equations there is no evidence of such behavior, although the results do not rule out such a response in a quarterly or monthly time frame.

The coefficients of the expected real interest rate are all negative, with three of the six t -ratios equal (in absolute value) to 4.0 or more. These coefficients multiplied by the average real interest rate are equal to the implied elasticities—the percent change in inventories corresponding to a 1-percent increase in the real interest rate. Thus, a coefficient of -2.0 and an average real interest rate of 0.04 would imply an elasticity of 0.04 times -2.0, or -0.08. Because of the lag of the expected behind the actual rate, this response builds up gradually as an actual change is incorporated into expectations. The coefficients of the unexpected real interest rate are small and not significant statistically.¹⁶

All of the equations include a correction for first-order serial correlation in the residuals. The autocorrelation coefficients range from 0.42 to 0.99, implying that the unexplained variation in inventories changes smoothly even on an annual basis.

Chart 8 shows the levels of materials inventories, new orders, and the expected real interest rate for the orders group of industries. The chart, like the equation for this category in table 3, suggests that (1) inventories respond to a smoothed version of new orders, and (2) inventories respond

12. This expression can be derived mathematically as the magnitude a profit-maximizing firm will set equal to the value of the marginal product of its stock of inventories if all of its interest costs are deductible expenses, and if a fraction, f , of the increase in the value of its inventories during the period in which they are held are subject to tax.

13. See Albert A. Hirsch and Michael C. Lovell, *Sales Anticipations and Inventory Behavior* (New York: Wiley & Sons, 1989), chapt. 5, especially pp. 116-28.

14. The separation is based on the equation $XE_t = a + b(X_{t-1} + XE_{t-1})$, where XE_t is the expected value of the real rate in year t , and X_{t-1} and XE_{t-1} are the actual and expected real rates in year $t-1$. The procedure for estimating a and b is described in Frank de Leeuw and Michael J. McKevey, "The Realization of Plans Reported in the BEA Plant and Equipment Survey," *SURVEY* 51 (October 1981): 36-37.

15. If K_t the logarithm of the level of inventories, is equal to $aS_{t-1} + b(S - S_{t-1})$, where S is logarithm of sales, then K can also be expressed as $bS + (a-b)S_{t-1}$. When a is positive and b is positive but smaller than a , then this alternative expression shows that K depends positively on both S and S_{t-1} .

16. Note that if inventories were related to the current actual real interest rates, and the split into expected and unexpected components were irrelevant, then the coefficients for the expected and unexpected components should be the same. In fact, they are significantly different.

negatively to the expected real rate, accounting for the increase in inventories relative to orders in the mid-1970's.

A number of alternative specifications were tested on annual data, with qualitatively similar results but some important quantitative differences. These results can be summarized briefly:

- (1) Equations without an autocorrelation correction had on average,

larger and more significant negative coefficients for the real interest rate and somewhat larger coefficients for sales and new orders.

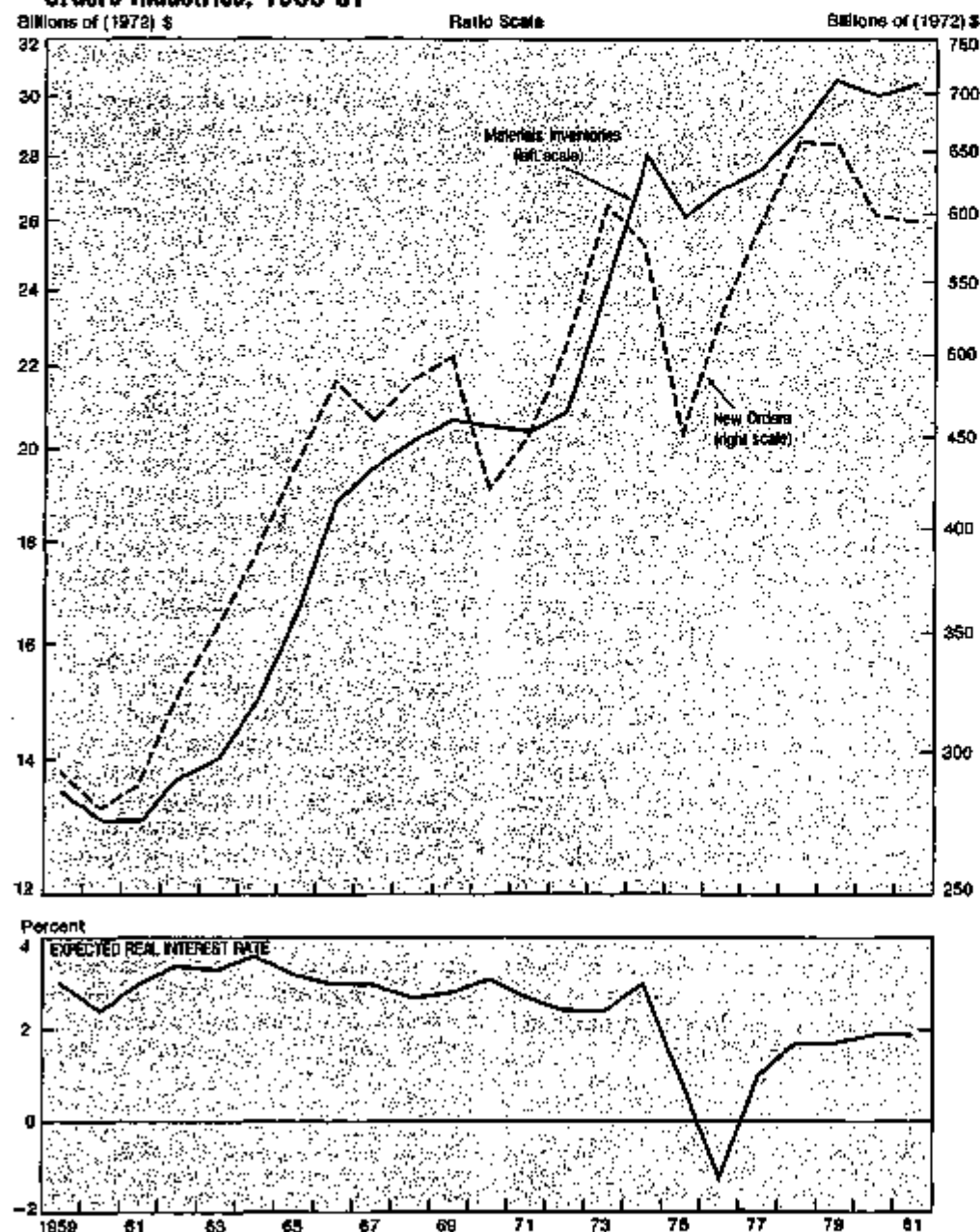
- (2) Replacing the "expected" and "unexpected" disaggregation of the real interest rate by a disaggregation into current level and current change—parallel to the treatment of sales and new orders—generally reduced the real interest rate coefficients, al-

though they all remained negative.

- (3) Replacing the level-and-change disaggregation of the demand variables by disaggregation into "expected" and "unexpected" levels—parallel to the treatment of the real interest rate—increased the coefficients of expected sales or new orders and decreased coefficients of the expected real interest rate, although the latter all remained negative.
- (4) A stock-adjustment specification of the basic equation, in which the logarithm of inventories depends on the logarithm of current sales or new orders, the current real interest rate, and the lagged stock of inventories, implied lags somewhat longer than the results shown in table 3.
- (5) Splitting the expected real interest rate into two components with separate coefficients, an expected interest-rate component and an expected price-change component, resulted in insignificant and generally positive interest-rate coefficients (contrary to hypothesis) and significant positive price-change coefficients (in accordance with hypothesis).
- (6) Finally, an additional variable, the ratio of materials prices to final product prices, which would be expected to have a negative relationship to inventory holdings, had three negative coefficients and three positive coefficients.

CHART 8

Materials Inventories, New Orders, and Expected Real Interest Rate: Orders Industries, 1959-81



Quarterly results.—Results of the quarterly versions of these equations, which appear in table 4, differ from those of the annual versions in major respects. The coefficients of levels of sales and new orders remain positive and significant, but average 20 percent lower than the corresponding coefficients in the annual equations. Coefficients of the expected real interest rate remain negative, but are much smaller and less significant.

Quarterly results based on alternative specifications also tended to diverge from the annual results. For example, a stock-adjustment model fit to quarterly data implied considerably longer lags than those implied by annual stock-adjustment equations, which, as noted earlier, imply lags

somewhat longer than the equations reported in table 3.

The annual equations appear to be more trustworthy than the quarterly ones. The annual variables are subject to smaller measurement errors, and the divergences in results are those that might be expected because of the nature of the quarterly measurement problems. For example, a quarterly dependent variable that is too smooth could easily increase the estimated length of lags; and errors in measuring the real interest rate could easily bias its coefficients towards zero.

Although the annual regression results reported in table 3 seem preferable to regressions based on quarterly data, quarterly equations are necessary in order to determine how demand and cost factors contribute to the destabilizing behavior of manufacturing inventories. What is desired is a set of quarterly equations subject to the constraint that the long-run responses to demand and to expected real interest rates are in accord with the annual results in table 3. The appendix describes the way in which such equations were estimated.

Simulation Results for Manufacturers' Inventories

The constrained quarterly inventory demand equations described in the appendix are used in this section in two ways: (1) to analyze the causes of the destabilizing behavior of manufacturers' inventories, and (2) to illustrate the typical effect on manufacturers' inventories of a step change in sales or new orders and a step change in the real rate of interest. Table 5 and 6 show the results of these simulations.

Accounting for destabilizing behavior

The equations developed in the previous section and the appendix permit an allocation of the destabilizing behavior of manufacturers' inventory investment to the influences of current and lagged sales or new orders, and the real interest rate. The measure of destabilizing behavior developed in the first part of this article can be disaggregated into the contribution of each explanatory variable in the demand equations. Because the

Table 4.—Demand Equations for Inventories: Quarterly Regression Results

	Sales Industries			Orders Industries		
	Finished goods inventories	Goods in process inventories	Materials inventories	Finished goods inventories	Goods in process inventories	Materials inventories
Constant.....	0.10 (0.1)	-3.90 (-16.2)	-1.83 (-3.7)	1.97 (6.0)	0.78 (2.4)	0.86 (1.3)
Logarithm of sales or new orders lagged four quarters.....	.57 (4.2)	1.18 (24.3)	.86 (11.4)	.18 (2.6)	.55 (7.3)	.52 (6.8)
Change in logarithm of sales or new orders lagged three quarters.....	.42 (2.9)	1.03 (10.4)	.85 (6.7)	.15 (2.1)	.44 (6.5)	.44 (6.2)
Lagged two quarters.....	.41 (2.8)	.86 (9.3)	.71 (7.0)	.08 (1.4)	.29 (4.9)	.32 (4.9)
Lagged one quarter.....	.51 (3.6)	.75 (7.3)	.98 (11.1)	.03 (0.6)	.15 (3.1)	.17 (3.1)
Current.....	.12 (1.2)	.44 (5.0)	.15 (1.7)	-.02 (-.6)	.07 (2.0)	-.02 (-.5)
Expected real interest rate ¹	-.87 (-2)	-.50 (-1.7)	-.63 (-2.6)	-.72 (-1.4)	-1.41 (-2.7)	-1.41 (-2.7)
Unexpected real interest rate ¹.....	.02 (.3)	.08 (1.1)	.03 (.5)	-.15 (-1.5)	.03 (.4)	-.22 (-2.2)
R ².....	.384	.987	.896	.395	.987	.896
Autocorrelation coefficient.....	.98	.98	.95	.99	.98	.93
D-W.....	1.3	1.9	1.5	1.2	.9	1.0

Note.—The dependent variables are logarithms of the levels of inventory stocks at the end of each year. Numbers in parentheses are t-ratios.

1. The real interest rate is expressed in decimal form; e.g., 4 percent is 0.04. Separation into expected and unexpected components based on formula $EX_t = A + b$

$$[(\sum_{i=1}^4 X_{t-i}) + XE_t]$$

where XE_t is the expected rate in quarter t , X_{t-1} is the actual rate lagged 1 quarter, and XE_{t-4} is the expected rate four quarters ago. Estimates of a and b are based on annual data; see note to table 3 and text.

measure of instability is not additive and because the equations do not fit perfectly, the disaggregation does not provide an exact accounting for the contribution of each variable, but only strong indications of which are most important. Note that the equations explain levels of inventories, whereas what contributes to stability or instability is inventory change. It is, therefore, changes in the explanatory variable of the demand equations that account for the stabilizing or destabilizing behavior of inventory investment.

The results, shown in table 5, indicate that destabilizing behavior of manufacturers' inventory investment in all three stages is overwhelmingly due to the influence of lagged changes in sales and new orders, that is, lagged changes in demand. The table shows the separation of the total measure of instability into three components: the contribution of the acceleration or deceleration of demand in the current and previous quarter, the contribution of changes in demand in all earlier quarters, and the contribution of changes in the expected real interest rate (the impact of the unexpected rate, with its small and insignificant coefficients, is not shown in the table). For all three stages, the second factor, the contribution of lagged changes in demand, is highly destabilizing. These lagged changes

Table 5.—Disaggregation of the Measure of the Contribution of Manufacturing Investment to Instability, 1959-81

	(Percent)		
	Finished goods inventories	Goods in process inventories	Materials inventories
Total.....	-1.6	7.6	5.2
Contribution of demand:			
Acceleration/deceleration during current and previous quarter.....	-.4	.2	-.1
Changes in all earlier quarters.....	4.6	14.5	13.4
Contribution of changes in expected real interest rate.....	-.4	-.9	-1.0

Note.—The measure is described in the text and in the note to table 1. The totals in this table are taken from column 1 of table 1. The additivity of the measure is discussed in footnote 5.

are less destabilizing for inventories of finished goods, for which the long-term coefficients of the demand variables are relatively small, than for inventories in other stages. Evidently, cycles in demand last long enough that reductions in inventories in response to past weakness typically take place while demand is still below trend; and inventory buildups in response to past strength in demand typically take place while demand is still above trend.

The contributions of the other factors in the table are much smaller. The response of inventory investment to the current acceleration or decel-

eration of demand makes a small stabilizing contribution for finished goods inventories and has a impact close to zero for the other stages. The contribution of changes in the expected real interest rate is also mildly stabilizing; evidently, the correspondence of expected increases in real interest rates with an expansion or expected decreases with a contraction, which would give rise to such behavior, are more common than the opposite situations.

The typical response to demand and real interest rates

The results of this study can be shown in the form of typical responses of manufacturers' inventory investment to a 1-percent increase in sales and new orders and to a 1 percentage point increase in the level of real interest rates. The latter change could be caused by a change of 1 percentage point in the bank interest rate on short-term business loans, or by a change of roughly 0.6 percentage points in the rate of inflation (the exact amounts depend on the industry distribution of the changes). Among other uses, these calculations may help forecasters in judging the sensitivity of manufacturers' inventory investment to variations in projected real growth rates, interest rates, and inflation rates.

The calculations are summarized in table 6, assuming end-of-1981 inventory stocks in order to translate percent changes into dollars of inventory investment. For a 1-percent step increase in sales or new orders, the response of investment in finished goods inventories is the smallest of the three stages; it begins at \$0.18 billion in 1972 dollars the quarter of the increase, rises to \$0.34 billion two quarters later, and then falls to zero. The responses of investment in inventories of goods in process and inventories of materials are larger, reaching peaks of \$0.43 billion and \$0.71 billion. The three stages together reach a peak of \$1.48 billion in the third quarter of the upward shift in sales and new orders.

For a 1 percentage point increase in the real interest rate, the response of investment in finished goods inventories is again smallest, starting at -\$0.28 billion in 1972 dollars, quickly

dropping to about one-half that amount, and then in the second year approaching zero. The response of investment in materials inventories is largest, beginning at -\$0.80 billion, then dropping to just under -\$0.50 billion for three quarters, to just over -\$0.10 billion for the second year, and then to near zero. In total, manufacturers' inventory investment has its strongest response—\$1.32 billion—in the initial quarter. Thus, according to these results, projections of inventory investment ought to take interest rates and inflation rates, as well as sales and new orders, into account.

Appendix: Constrained Quarterly Equations

The easiest method of estimating quarterly equations constrained by annual long-run responses is to construct a set of quarterly dependent variables of the form:

$$\log K_t - b_1 \log D_{t-1} - b_2 RE_t$$

where K is an inventory category, D is the demand variable (sales in three of the six equations, new orders in the

Table 6.—Responses of Manufacturing Inventory Investment to a Step Change in Sales or New Orders and in Real Interest Rates: Initial Inventory Levels of End of 1981

(Billions of 1972 dollars, seasonally adjusted at annual rates)

Quarters after step change	1-percent increase in sales or new orders (1972 dollars)			1 percentage point increase in real interest rate		
	Finished goods inventories	Goods in process inventories	Materials inventories	Finished goods inventories	Goods in process inventories	Materials inventories
1	0.18	0.35	0.28	-0.28	-0.24	-0.30
2	.23	.36	.62	-.16	-.30	-.45
3	.34	.43	.71	-.15	-.32	-.47
4	.13	.41	.35	-.18	-.30	-.45
5	.17	.32	.06	-.44	-.07	-.11
6	0	0	0	-.03	-.07	-.12
7	0	0	0	-.05	-.07	-.12
8	0	0	0	-.04	-.09	-.11
9	0	0	0	-.01	-.02	-.04
10	0	0	0	-.01	-.02	-.02

Table 7.—Demand Equations for Inventories: Constrained Quarterly Regression Results

	Sales industries			Orders industries		
	Finished goods inventories	Goods in process inventories	Materials inventories	Finished goods inventories	Goods in process inventories	Materials inventories
Coefficients imposed from annual results:						
Logarithm of sales or new orders lagged four quarters	0.61	1.19	0.84	0.37	0.86	1.00
Expected real interest rate	-.08	-.63	-1.98	-1.81	-2.53	-5.00
Estimated coefficients:						
Constant	-1.068 (-35.5)	-2.951 (-379.3)	-1.274 (-30.5)	-1.129 (11.3)	-.657 (-6.1)	-1.587 (-21.1)
Change in logarithm of sales or new orders:						
3-quarter lag	.684 (7.1)	1.649 (12.2)	.974 (10.7)	.299 (9.3)	.704 (20.3)	.868 (24.2)
2-quarter lag	.630 (6.3)	.875 (9.6)	.816 (8.6)	.210 (6.0)	.500 (11.0)	.652 (11.6)
1-quarter lag	.359 (3.8)	.760 (5.5)	.472 (5.9)	.105 (2.4)	.273 (5.5)	.360 (6.2)
Current quarter	.195 (2.0)	.448 (5.2)	.174 (1.9)	.013 (.4)	.123 (3.3)	.063 (1.3)
Unexpected real interest rate	-.028 (.4)	-.076 (1.2)	-.002 (.0)	-.170 (-1.8)	.019 (.2)	-.260 (-2.2)
R ²	.93	.88	.89	.90	.97	.93
Autocorrelation coefficient	.96	.82	.92	.90	.97	.93
D-W	1.2	1.8	1.3	1.1	.9	.6

Note.—The dependent variables are logarithms of the levels of inventory stocks at the end of each year. Numbers in parentheses are t-ratios.

others), RE is the expected real rate of interest, and b_1 and b_2 are the coefficients of lagged demand and of the expected real rate reported in table 3. These dependent variables are related to current and lagged changes in the logarithms of D and to the unexpected component of the real interest rate. Their coefficients determine the lag structure of the relationship of inventories to demand and cost; they do not influence the long-run responses.

Results of this procedure are shown in table 7. Each current or lagged

change in demand is entered as a separate variable.

With few exceptions, the coefficients in table 7 imply that the long-run responses built into the equations develop gradually over four quarters. For example, in the equation for finished goods inventories in sales industries, the long-run coefficient of the logarithm of sales four quarters ago is constrained to be 0.81, and the coefficients on current and lagged changes are 0.195, 0.359, 0.630, and 0.684. The net coefficient on the current levels is

0.195; on the previous quarter's level, 0.359–0.195, i.e., 0.164; on the level two quarters ago, 0.630–0.359, i.e., 0.271; on the level three quarters ago, 0.684–0.630, i.e., 0.054; and on the level four quarters ago, 0.811–0.684, i.e., 0.127. All coefficients are positive, implying a gradual buildup of the response of inventories to sales. By design, the sum of these five coefficients equals 0.81. With only one exception, coefficients of the unexpected real interest rate, also shown in table 7, are not significant.